Nature Conservation 22: 191–218 (2017)
doi: 10.3897/natureconservation.22.10711
http://natureconservation.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

# Integration of species and ecosystem monitoring for selecting priority areas for biodiversity conservation: Case studies from the Palearctic of Russia

Alexey A. Romanov[1], Elena G. Koroleva[1], Tatyana V. Dikareva[1]

1 *Dept. of Biogeography, Faculty of Geography, Moscow State Lomonosov University, Moscow, Russia*

Corresponding author: *Alexey A. Romanov* (romanov.alexey63@mail.ru)

Academic editor: *K. Henle* | Received 3 October 2017 | Accepted 22 August 2017 | Published 1 November 2017

*http://zoobank.org/93B9B3A4-78A0-49CD-AD81-EC0F55A95F53*

**Citation:** Romanov AA, Koroleva EG, Dikareva TV (2017) Integration of species and ecosystem monitoring for selecting priority areas for biodiversity conservation: Case studies from the Palearctic of Russia. Nature Conservation 22: 191–218. https://doi.org/10.3897/natureconservation.22.10711

## Abstract

At the start of the third millennium, new opportunities have arisen in biogeographical research, namely in the generalisation, visualisation and cross-spectrum analysis of biological and geographical information and in the compilation of biogeographical maps and innovative models for regions that differ in the availability of distribution data. These tasks include long-term monitoring of plants and animals which are in danger of extinction, geographical analysis of biodiversity distribution and development of effective wildlife conservation strategies for specific regions. The studies of the Department of Biogeography of Moscow University on geography and biodiversity conservation are based on long-term field expeditions. The examples of the Asian Subarctic Mountains, the steppes of Central Kazakhstan and the urbanised north-west of Russia are used to illustrate Russian approaches to the use of biogeographical monitoring for the identification of priority areas for biodiversity conservation. The species populations of the higher plants and vertebrates listed in the Red Books have been considered as the basic units of biodiversity.

## Keywords

biodiversity, biogeographical mapping, monitoring, wildlife conservation

## Introduction

Biodiversity analysis is an actively developing method for assessing the Earth's living state. Biodiversity analysis affects not only relevant fields of scientific knowledge, but also the scope of the states' international obligations to preserve the diversity of life in their territories. Preservation of biodiversity is currently regarded as one of the priorities of the states' sustainable development. The contribution of Northern Eurasia, a territory of Russia and its bordering countries, to the global biodiversity of the planet is exceptionally large. The global role of the states in this area is estimated first by assessing the biosphere functions and ecosystem services provided by the respective biota and ecosystems. Due to the preservation of natural landscapes, the number of the functions and services existing in Russia constitutes about 10% of the world's entire quantity of such functions and services (Tishkov 2002).

As previous attempts to protect the species listed in the Red Books have shown, patronising protection or cultivation of these species in artificial conditions without attempts to protect and recover the ecosystems do not give the desired result (Velasco et al. 2015).

One stage of biodiversity conservation strategy is *quantitative and comparative assessment* in natural ecosystems at different levels. Mere inclusion in the federal and regional Red Books is insufficient; without identifying rare species, establishing their status and range boundaries, defining factors that have a negative effect on their populations, organising habitat protection and undertaking regular monitoring, the majority of the species in the Red Books would become extinct. Therefore, an essential responsibility of conservation programmes for rare species is to monitor the status of their various regional groups (i.e. the populations of the species) within the range of the state. For the next stage – the cartographic stage – *biogeographical maps* are created of various subject matters; these maps spatio-temporally integrate the different scales and types of information (Ogureeva 2012).

There are many articles in the non-Russian literature on the global and regional aspects of the assessment and conservation of biodiversity. These articles are devoted to species distribution modelling (Franklin 2010, Gallien et al. 2010, Scoble and Lowe 2010), defining priorities for networks of protected areas (Cadotte and Davies 2010, Ferrier and Drielsma 2010, Kraft et al. 2010, Proença and Iknayan 2014), identifying threats to biodiversity from invasive species (Gallien et al. 2010, Leung et al. 2010, Thuiller et al. 2010) and determining biodiversity responses to climate changes (Ackerly et al. 2010, Franklin 2010, Thomas 2010). The criteria for identifying the conservation value of the territories have been studied in the articles of Drechsler and co-authors (Drechsler 2005, Drechsler et al. 2009). However, the experience of Russian biogeographers in the Palearctic has received little attention.

The aim of this study is to summarise the experience of long-term monitoring, mapping and assessment of rare and protected plant and animal species at various spatial scales and levels in Russia. The basic units of biodiversity considered were species, families and populations of protected plant and animal species. Different parts of the

Palearctic were selected on the basis of the area's biogeographic zoning: the Russian Subarctic (Putorana Plateau), the steppe zone of Central Kazakhstan and the urbanised north-west of Russia (Kaliningrad region).

## Case study 1: Putorana Plateau

The Putorana Plateau is a remote and under-explored region of the Russian Arctic that is located almost entirely north of the Arctic Circle. This is one of the few vast regions of the Central Palearctic that has unusually diverse northern taiga fauna and an admixture of tundra and mountain elements. The Putorana Plateau is a significant region that ensures biodiversity of the entire Palearctic. In 2010, its territory was designated as a UNESCO world cultural and natural heritage site.

The great extent of the plateau in both latitudinal and longitudinal directions and its clearly defined vertical zoning have resulted in great diversity and a unique combination of animal communities that are prevalent throughout the Palearctic (Romanov et al. 2014). Rare and endangered fauna species that are amongst the typical representatives in the plateau are included in the Red Books of the International Union for the Conservation of Nature (Walter and Gillett 1988) and the Russian Federation, but the current state of these species' populations is largely unknown. The specific natural conditions and lack of a permanent human population significantly impede conducting regular monitoring in this area. Existing data are sparse and fail to adequately describe the distribution, abundance and current state of the protected species' populations in the area. In 1989, the state wildlife preservation organisation "Putoranskiy" initiated ornithological research and made it possible, for the first time, to generate summarised results on two species that are under international protection: the lesser white-fronted goose (*Anser erythropus*) and the white-tailed eagle (*Haliaeetus albicilla*). The results obtained for both species are presented in this study.

The lesser white-fronted goose (*Anser erythropus* (Linnaeus, 1758)) is an endangered species with a continuously and drastically decreasing population and it is included in the Red Book of Russia (Pavlov 2001) and in the IUCN Red List (Walter and Gillett 1988). It is a category 2 threatened species. The range of the species in the Palearctic is highly fragmented and represents numerically insignificant, isolated, small-scale areas that are scattered along the river valleys and lake basins from the tundra of the Kola Peninsula to Chukotka.

Putorana Plateau is one of the largest and most under-explored parts of the species' range, including its borders and the number of breeding pairs. Over the last 35 years, the population has decreased to one-sixth of its original size – from 100,000 to 18,000. Of the remaining 18,000 animals, about 5,000 inhabit Taimyr which forms the southern boundary of the Palearctic (Morozov and Suroechkovskiy Jr. 2002).

The white-tailed eagle (*Haliaeetus albicilla* (Linnaeus, 1758)) is a widespread Palearctic species. Its range includes the entire territory of Russia, but no more than 2,500 pairs remain (Pavlov 2001).The species is included in the Red Book of Russia and the IUCN Red List-96. It is a category 3 rare species.

*Haliaeetus albicilla* is distributed widely throughout the vast area of the Eurasian territory. A similar pattern can also be seen in Siberia, where *H. albicilla* has always been the most common large bird of prey, with its greatest numbers in the northern taiga subzone (Rogacheva 1988). In the taiga, the boundaries, within which *H. albicilla* is located, almost completely coincide with the boundaries of the Putorana Plateau. On this plateau, there is the largest area of its breeding range which is also the area with the highest number of breeding individuals (Dorogov 1988, Volkov 1988, Zyryanov 1988, Romanov et al. 2007, Romanov and Rupasov 2009). *Haliaeetus albicilla* is very rare north and south of the Putorana Plateau, with only a few breeding pairs existing outside this area (Kozhechkin and Polushkin 1983, Kuznetsov et al. 2007, Kharitonov et al. 2007, Pospelov 2007).

## Environmental conditions

The Putorana Plateau is located at the extreme north-western tip of the Central Siberian Plateau (north of the Krasnoyarsk territory; 65°00'–71°00N; 90°00'–100°00E; (Fig. 1). The plateau is an array of basalt with flat tops and with an average elevation of 900–1200m above sea level (asl). The landscape is predominantly lowlands, with a maximum height of 1701m asl in the eastern part of the region. The altitudinal zonation comprises the northern-taiga (up to 600m asl) and the subalpine (600–800m asl) and alpine (800m asl) zone (Norin 1986). The climate of the Putorana Plateau is subarctic, with average January temperatures ranging from −32°C to −36°C and average July temperatures ranging from +8°C to 12°C. Summer is short; the polar day lasts less than one month (22 days) in the south and about 2 months (64 days) in the north. Winter is long, with a polar night from 22 to 60 days (Zemtsova 1976). The annual amount of precipitation ranges from 300mm in the northeast to 600mm in the southwest of the region. Due to the Putorana Plateau including subarctic areas of excessive moisture, as in other provinces, favourable conditions are created to maintain a dendritic and full-flowing water network. The surplus water in subarctic landscapes fills all concave forms of relief (potholes, bowls), leading to the formation of large tectonic oligotrophic-type lakes. The volume of water mass in the lake area of the plateau is the greatest in the Russian Subarctic. As the hydrography of Putorana is mainly determined by a tectonic snap system, the valleys and potholes from modern reservoirs form narrow and deep gorges and canyons and most rivers are mountain-type rivers: they are turbulent and full-flowing with many knickpoints. In winter, ice blisters form on the largest of the rivers; in summer, there are frequent high-level protracted floods. While the central and southern parts of Putorana Plateau are located in the northern taiga subzone, most of its territory is above the tree line.

Therefore, widespread mountain–tundra landscapes within the belt occupy about half of the territory in the south and most of the territory in the central part. Amidst the mountain landscape, integral, separate and unique fauna complexes have been formed, such as forest (mountain–northern taiga), golets (mountain–forest tundra)

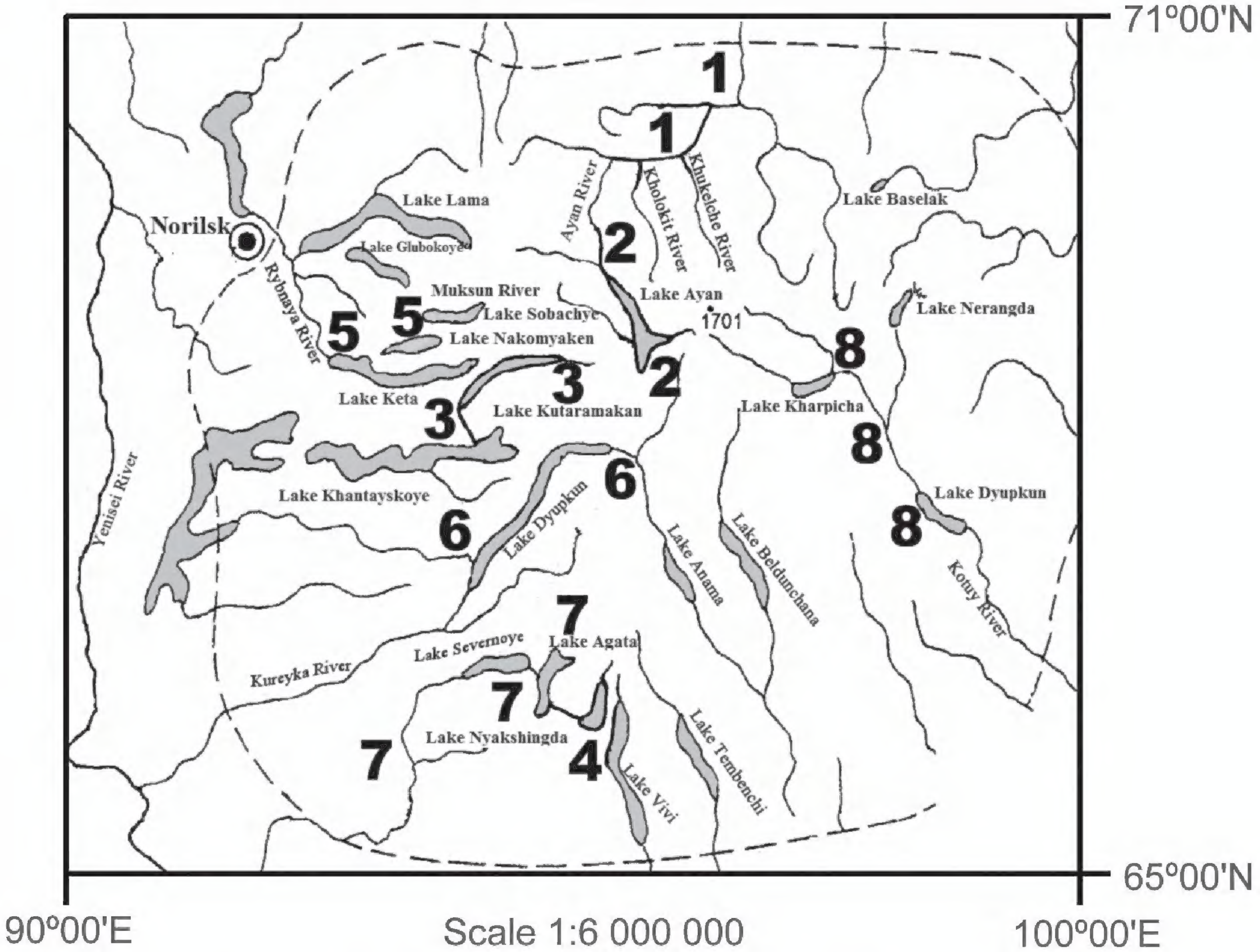


**Figure 1.** Areas and years of ornithological research on the Putorana Plateau: **1** Northern regions (Lake Bokovoye; rivers: Ayan, Ambar, Munil, Nerakachi, Dakit, Kholokit, Khukelche), 1989 **2** Central regions (Lake Ayan, Lake Kapchug; rivers: Amnundakta, Gulyami, Bolshoy Khonna-Makit, Kapchug), 1988 **3** Western regions (lakes: Kutaramakan, Kapchuk, Khantayskoye; rivers: Verkhniy Kutaramakan, Kutaramakan, Kapchuk, Bogadil, Irkinda), 1990 **4** Southern regions (Lake Nyakshingda, Lake Vivi; rivers: Amundykan, Verkhnyaya Nyakshingda, Nyakshingda, Irbukon, Morktakon, Sengan), 1991 **5** Western regions (lakes: Keta, Nakomyaken, Sobachye, Glubokoye; rivers: Nahta, Mikchangda, Muksun), 1999, 2004, 2008 **6** South-west (Lake Dyupkun Kureiskiy; rivers: Kureyka, Yagtali), 2001, 2006 **7** South-western regions (lakes: Agata Verkhnyaya, Agata Nizhnyaya, Severnoye; rivers: Oron, Epekli-Sen, Severnaya), 2003 **8** Eastern regions (lakes: Kharpicha, Dyupkun Kotuiskiy, Lyuksina; Kotuy River), 2007. Traditional border of Putorana Plateau.

and sub-golet (mountain–tundra) belts (Nikolaev 1999). These areas do not have identical counterparts in the other mountain systems in Northern Eurasia and, therefore, are independent, valuable objects of research and protection. Expeditionary research on the Putorana Plateau from 1988–2008 is presented in Figure 1.

## Materials and methods

Recording and monitoring of the populations of rare and endangered Palearctic avifauna were undertaken from 1988 to 2008 (during 13 summer seasons from May

to August). Field parties of two to four people were organised to walk overland and to navigate water routes by boat. The expeditionary groups' equipment consisted of navigational aids, special optical equipment, individual telemetry tracking devices for birds, items for labelling and standard field equipment for field research in the Arctic. During this period, an area of about 200,000km$^2$, including 11 large tectonic lakes, was investigated. All the material was collected using survey routes. The total length of the overland survey routes was 8,617km and that of water routes was 1,516km. While traversing the routes, the researchers visually assessed all species of birds and their status (such as nomadic, breeding, hunting). The investigation also included assessing the borders of territorial pairs as well as areas potentially suitable for the birds to breed. Fixed surveillance of the birds' flight during the migration season and daily monitoring of the nests during the breeding season were undertaken.

The breeding accuracy was estimated according to the criteria recommended by the European Ornithological Atlas Committee (EOAC) (Hagemmeijer and Blair 1997). Records of *H. albicilla* registered as living in nests and in territorial pairs were drawn on to maps. For remote areas, the number of individuals was estimated by abundance extrapolation based on an expert assessment of habitat suitability using topographic maps at the scale of 1:500,000 and 1:200,000 and using satellite Landsat images. At the first stage, all areas that were similar to areas in which *H. albicilla* was observed breeding, were identified using satellite images and topographic maps. After confirmation of the birds' residence in these areas, the number of breeding pairs was extrapolated by taking into account the available space suitable for establishing breeding territories as well as the average size of nesting sites and distances between them (defined based on field and published data).

In addition to observations recorded along the same survey routes as for *H. albicilla*, *Anser erythropus* was studied by satellite telemetry. Adult moulted birds (n=6) accompanying litters were equipped with plastic collars with fixed satellite "NORTH STAR" transmitters at nesting sites in the south-west of Putorana. The transmitters allowed the birds' locations to be traced for eight months. The telemetry data were processed using Argos-tools (http://gis-lab.info/programs/argos/index-rus.htm) and the Google Maps mapping service allowing the birds' movements to be traced in real-time (http://gis-lab.info/projects.piskulka.html) using scalable space Landsat images. Uncertainty in object position did not exceed 10 m. Descriptions of the habitats in the resting areas during migration were compiled using large-scale maps, space images and regional physico-geographical summaries (Gvozdetskiy and Mikhailov 1978, Dementiev 1979, Proshin 1979), as well as questionnaires (V.A. Arkhipov and E.A. Zhuravlev, pers. comm.). Faecal samples from *A. erythropus* were also analysed in the breeding area.

## Results and discussion

The collected data allowed identification of the nesting area, estimation of the number of breeding birds and an assessment of the breeding habitat and migration. Figure 2

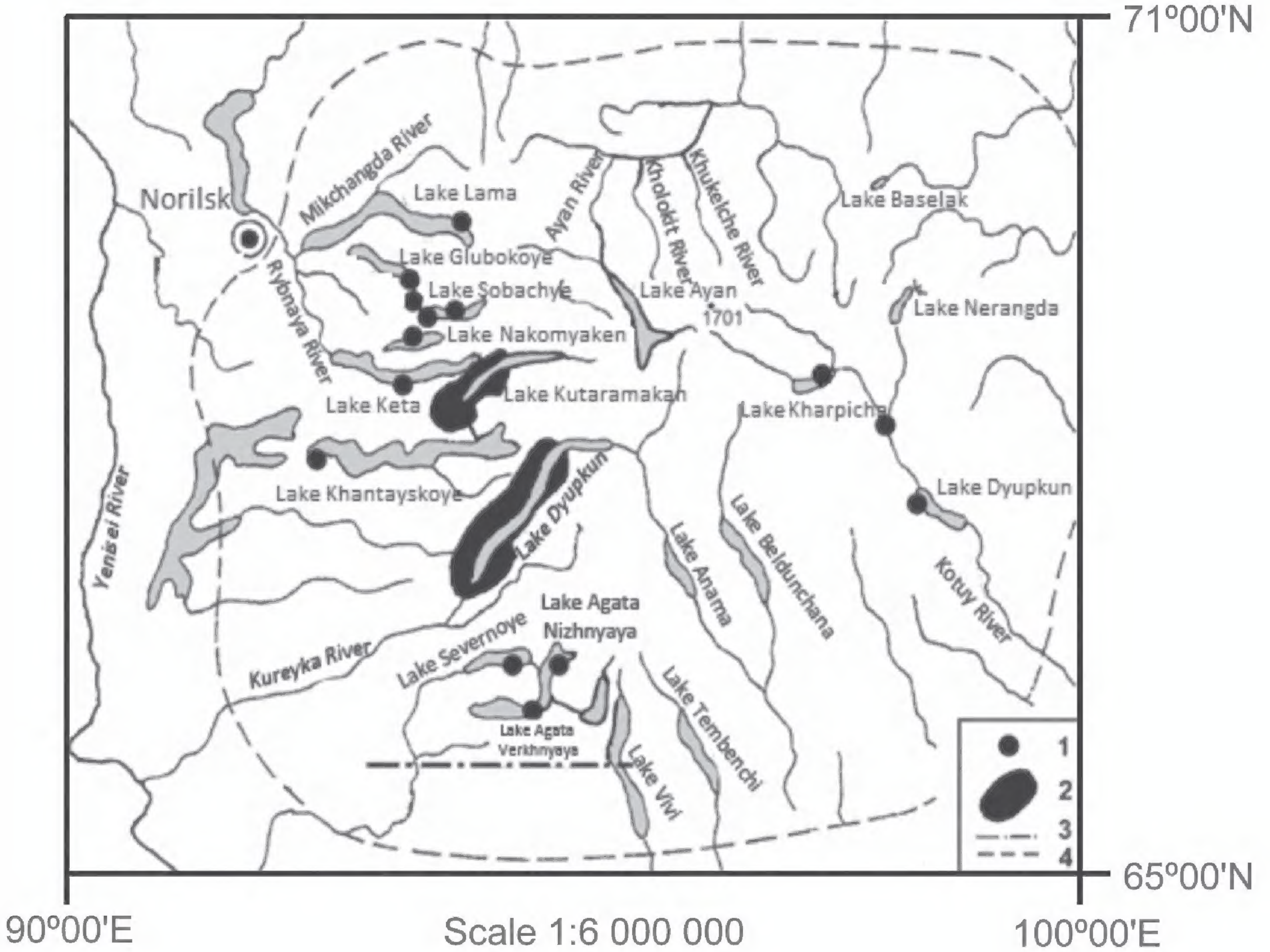


**Figure 2.** Distribution of *Anser erythropus* during the nesting period on Putorana Plateau. **1** meeting points of territorial pairs, litters and non-breeding individuals **2** long-term successful nesting areas **3** southern boundary of breeding range; 4: Putorana Plateau border.

shows stable and relatively large core areas for breeding of *Anser erythropus* which are consistently formed on the lakes in the western part of the Putorana Plateau: Kutaramakan (30–40 breeding pairs), Dyupkun (60–100 pairs) and Agata Nizhnyaya and Severnoye (10–15 pairs). At least 220 pairs nest each year in the surveyed 35,000km$^2$ territory. The largest nesting swarm on Lake Dyupkun belongs to one of the largest swarms on the Taimyr Peninsula, with an average occurrence of two pairs of geese per 10km of coastline (excluding the mountainous northeast segment, where there are 2.5 pairs/10km). A small group of 10–12 pairs was present in the eastern part of the Putorana Plateau in the Kotuy riverheads. Although a population of *A. erythropus* may nest on the Vivi, Tembenchi, Annama and Beldunchana lakes, these lakes have not been investigated. Long-term monitoring results allowed the southern line for the distribution of *A. erythropus* to be drawn 250 km further south of the Keta and Kutaramakan lake potholes than previously thought. According to our updated data, the nesting area of *Anser erythropus* completely covers the western part of the Putorana Plateau, extending southwards to 66°5. The southern border extends through the system of two lakes: Agata Verkhnyaya and Agata Nizhnyaya (Fig. 2). Putorana Plateau has therefore been conclusively shown to be the southernmost point for the distribution of

*A. erythropus* on the Taimyr Peninsula which is a key region for the species' reproduction within the Taimyr sector in its range. The number of breeding birds in this region comprises 10–15% of the Taimyr population.

The critical nesting factor in Putorana is the presence of a wide flat coastal area of the lakes with sedge–mixed herbs and osier. These areas, extending for tens of kilometres along the lacustrine coast, provide the geese with both plentiful, easily accessible food and secure hiding places in case of danger. The average nesting density in the most favourable habitats is two pairs per 10 km of coastline. The average litter size (n=59) is four chicks.

Telemetry tracking has shown that the Putorana population hibernates in Syria and Iraq, migrating through Western Siberia, Kazakhstan, the Caspian Sea, Iran and Turkey. These migration routes are part of the global migration flows that are common to the population of *A. erythropus* breeding in the western half of its range, from Western Taimyr to Southern Yamal and Northern European (Fig. 3). Within the range of the full annual life cycle, the Putorana *A. erythropus* are most vulnerable at their migration stops, especially in Northern Kazakhstan, where people actively hunt waterfowl (Morozov and Syroechkovskiy Jr 2002, V.A. Arkhipov and E.A. Zhuravlev, pers. comm.).

The results of monitoring other protected species, i.e. the *white-tailed eagle (Haliaeetus albicilla)*, provided the basis for the assertion that the modern state of this species' nesting on Putorana Plateau is stable. There were no drastic changes in the number of the species in the past decade. An average of one territorial pair travels within about 1,176 km$^2$ and the forest landscapes in which *H. albicilla* nests comprise no more than 50% of the plateau area — about 500–580 km$^2$ (Romanov 2009). The relative abundance of the species per 10km of the route is shown in Table 1.

Table 1 shows that the average distance between adjacent nests varies from 11.7 to 39 km and the maximum concentration of nests is registered in the Ayan river valley. In comparison, nests were found every 10–20 km at the end of the 1950s and the beginning of the 1960s to the west of Keta lake and in the Rybnaya and Khantayka river valleys. The records of Dorogov (1988), who investigated extensive areas of Putorana Plateau in 1975–1986, showed that, on average, nesting pairs were found every 25–30 km in the lake or river valleys. The minimum distance between two adjacent nests was 6–7 km in the Ayan river valley (Dorogov 1988), 15 km at the Kotuy riverhead (Dorogov 1988) and 6 km at the Kholokit riverhead (survey data).

In early spring, the wellbeing of *H. albicilla* on Putorana Plateau is directly related to the abundance of carrion and the remains of prey left by terrestrial predators and the nesting areas of most pairs coincide with the areas of wild reindeer mass migration. The shift in the main reindeer migrations from western to eastern Putorana during 1970–1980 was probably one of the most significant factors that negatively affected *H. albicilla* population dynamics in some western areas of Putorana. However, the reduced number of nesting pairs on the western plateau did not mean an automatic reduction in the overall number of Putorana family groups. Following the reindeer migration routes indicated a smooth transition of breeding *H. albicilla* into the interior and eastern regions of the plateau.


**Figure 3.** Flight scheme of *Anser erythropus* based on the results of telemetry tracking. Note: **1, 2, 3** flight trajectories of three lesser white-fronted geese; **A** Azerbaijan; **B** Armenia; **C** Syria.

Overall estimates show that about 170 pairs nest in the Putorana Plateau territory, of which at least 70 pairs nest in potholes of western lakes (Romanov and Rupasov 2009). Based on data from the Red Book of the Russian Federation (Pavlov 2001) on the number of individuals in Russia (about 2,500 pairs), the Putorana population accounts for about 7% of the total number of *H. albicilla* in Russia or 17% of the total number nesting in Siberia (Romanov 2009). These calculations show that Putorana Plateau is a key area for the species' reproduction in the Asian part of Russia. Its population may be affected negatively by harvesting old-growth forests on floodplains,

**Table 1.** Number of white-tailed eagles on Putorana Plateau.

| Location | Route length (km) | Survey year | Number of breeding pairs | Average number of breeding pairs per 10 km of the route | Average distance between neighbouring occupied nests (km) | Source |
|---|---|---|---|---|---|---|
| Middle reach of the Ayan River | 70 | 1989 | 6 | 0.86 | 11.7 | Romanov and Rupasov 2009 |
| Pothole of Lake Ayan | 70 | 1988 | 4 | 0.57 | 17.5 | Romanov and Rupasov 2009 |
| Pothole of Lake Kutaramakan | 80 | 1990 | 4 | 0.5 | 20 | Romanov and Rupasov 2009 |
| Potholes of the lakes Nakomyaken, Sobachye and the eastern terminus of Lake Glubokoye | 100 | 1999 | 4 | 0.4 | 25 | Romanov and Rupasov 2009 |
| Valley of the Mikchangda River | 110 | 2004 | 3 | 0.27 | 36.7 | Rupasov and Zhuravlev 2007 |
| Basin of the Severnaya River | 430 | 2003 | 11 | 0.26 | 39 | Romanov and Rupasov 2007 |
| Upstream of the Kotuy River | 100 | 2007 | 3 | 0.3 | 33 | Romanov and Rupasov 2009 |
| Upstream of the Kotuy River | 300 | 1983 | 4* | 0.13* | 75* | Dorogov 1988 |
| Upstream of the Kotuy River | 350 | 1984 | 5* | 0.14* | 70* | Volkov 1988 |

Note: * as a result of non-specialised records (without a targeted search for nests), the obtained data may be underestimated.

direct interaction with man, local and seasonal decreases in the abundance and availability of fish (this effect was especially reflected in summer nutrition) and reduction in the availability of carrion in the spring due to wild reindeer migration route changes (Romanov and Rupasov 2009).

The biogeographical features of Putorana Plateau, in particular its location within the boundaries of the Yenisei zoogeographic border which is one of the largest meridional biogeographic borders of Eurasia, support abundant biological and landscape diversity in the region, a transitional nature of the fauna and many endemic and rare species. The annual seasonal migration of the world's largest population of wild Taimyr reindeer (*Rangifer tarandus*) attracts many predators and acts as a regulator for these predators' distribution, abundance and reproductive behaviour. Thus, research and monitoring of *Anser erythropus* and *Haliaeetus albicilla* are considered top priorities and represent major international environmental challenges, demonstrating the need for maintaining the Russian Subarctic nature protection status for Putorana Plateau and for continuing research on rare and protected species in its territory.

## Case study 2: Kazakhstan

The problem of biodiversity protection is particularly acute in regions affected by global climate change. These regions include steppe landscapes with preserved relict plant

species and unique ecotopes, demonstrated by the forest outliers of the steppe region in Central Kazakhstan – the Pleistocene relicts of a single forest range that had contact with taiga forests of Western Siberia and with mountain and submontane forests of Altai in the cold and wet Pleistocene age. The presence of rare boreal and nemoral species surviving in these woods has led to the unique nature and high conservation value of these steppe landscapes. Amongst the total number of rare and endangered plants in Kazakhstan (about 600), 175 species reside in steppe landscapes.

The aim of this study was to assess the botanical diversity of Karkaraly National Park within the Karkaralinskie and Kent mountain ranges and the changes to this diversity during 2007–2014, in order to identify the most important ecotopes for rare and relict species in the studied region.

## Natural conditions

Kazakhstan is a large country located in central Eurasia. It covers an area of 2,715,000 km$^2$, stretching nearly 3,000 km from west to east and 1,600 km from north to south. The landscape in Kazakhstan is diverse. The Kazakh Hummocks and Karkaralinskie and Kent mountain ranges are located in the central part of the country (Fig. 4).

The climate in the republic is sharply continental. The average January temperature ranges from -19°C in the north to -5°C in the south and the average July temperature ranges from +17°C in the north to +31°C in the south. Summer is hot and torrid everywhere in the country. The temperature can reach +50°C. Winter in the country is dry and cold and the temperature can reach -58°C (Thomas 2010).

The research area is located within the Kazakh Hummocks and limited to the Karkaralinskie and Kent mountain ranges. The coordinates of the area are 49°25'00'N and 75°25'00E. The area of Karkaraly National Park, where most of the research was undertaken, is 112,120 ha.

By botanical–geographical zoning, the research area belongs to the Bayanaulsko–Karkaralinsko–Kent district in the Eastern–Kazakhstan sub-province of Zavolzhsko–Kazakhstan province in the Prichernomorsko–Kazakhstan sub-region of the Eurasian steppe region (Karamysheva and Rachkovskaya 1973). For the landscape, the Bayanaulsko–Karkaralinskiy hills form part of the Western Siberian-Kazakhstan steppe region in Central Kazakhstan, forming the Karkaralinskaya province (Nikolayev 1999).

The area covered by Karkaralinskie and Kent mountains is an ancient Paleozoic shield that, during Neogene-Quaternary time, underwent powerful geomorphological transformations that led to the modern look of these mountains, with their peaked ridges, abundance of screes and narrow, difficult-to-access canyons. The soil in the area is mainly represented by dark chestnut and mountain chestnut soils. The small islets of meadow chernozem soil is associated with mountain ranges and confined to river valleys. Intermountain valleys feature salt-washed chernozems and there are widespread solonetzic and alkaline soils in degradations (Nikolaev 1999).

At the end of the 19$^{th}$ century, the first serious geobotanical studies were performed in the Kokshetau forests by a professor at Kazan University, Gordyagin (1897). This

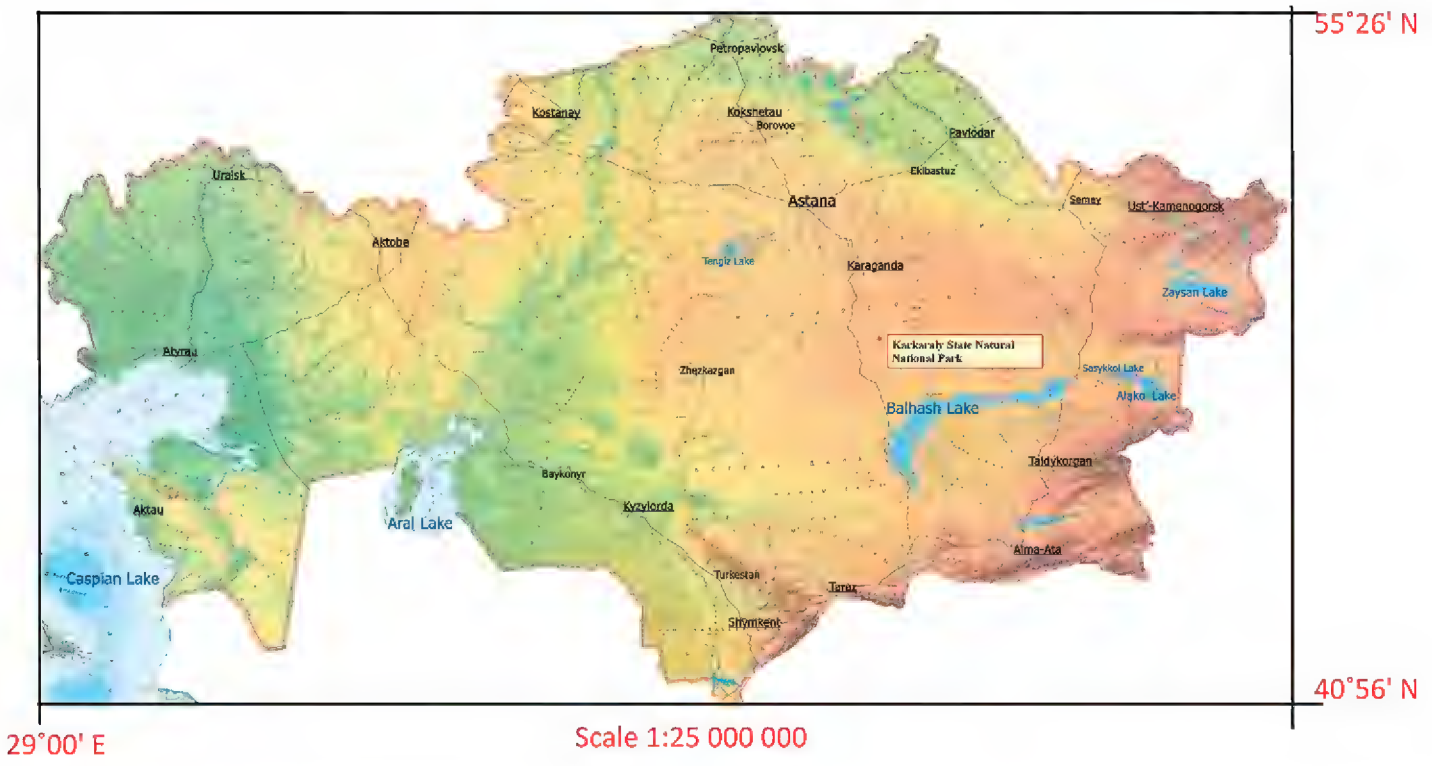


**Figure 4.** The research region in the Republic of Kazakhstan.

professor suggested that the forest outliers in the steppe region were a remnant of the single forest range which formerly connected the north to the taiga forests in Western Siberia and the east to the mountains and submontane forests in Altai. A similar idea was later expressed by Krasheninnikov (1939), who considered the steppe forest outliers to be the remains of a forest-steppe belt stretching from the Southern Urals to Altai during the cold and wet Pleistocene age.

The significant floristic unique nature of the East-Kazakhstan sub-province consists in the high percentage of species that have spread towards the east, such as the eastern Palearctic, eastern Kazakhstan, eastern Kazakhstan-Mongolic, eastern Kazakhstan and southern Siberian-Mongolic regions (Karamysheva and Rachkovskaya 1973). The presence of a wide range of humid boreal plant genera (e.g. *Chimaphila*, *Moneses*, *Pyrola*, *Orthilia*) is typical for this sub-province. All these genera grow in the low-mountain ranges of the Eastern Kazakhstan sub-province which is characterised by pine forests and open *Pinus sylvestris* forests and by the *Betula pubescens* birch gallery forest along streams and small rivers.

Pine forests mostly grow on mountain ranges with an understory of *Rosa spinosissima, Rosa majalis, Juniperus sabina, Lonicera tatarica, Padus avium* and *Crataegus sanguinea* which account for 71.3% of the total mountain forest area. Birch forests (*Betula pendula, B. pubescens*) are confined to the slopes with exposure to the north and northeast and to intermontane valleys along rivers and streams. Birch forests occupy 10% of the forested area. Aspen forests (*Populus tremula*) comprise about 2% of the forested country and are confined to relief depressions, valleys of rivers and streams and the base of round slopes.

Pine forest outliers are an amazing natural phenomenon of the western Siberian-Kazakhstan steppes. Conservation of these epibiotic complexes in the depths of the

steppe area favour specific edaphic conditions (loose, salt washed sands or granites). However, where the forests have been destroyed by people, natural recovery has become impossible. Many places have retained the names of forests that were lost long ago (Nikolaev 1999).

## Materials and methods

The materials for this study were compiled during expeditions during the summer (June and July) in 2007–2014. The area of research occupies a territory of about 100,000ha in the Karkaralinskiy and Kent mountain ranges, the steppe river valleys and the intramontane bolted areas. Monitoring of rare and relict species was undertaken both in the interfluvial zones and in the mountains. Routine geobotanic descriptions have been made, floristic lists on each type of ecotopes have been compiled and a herbarium has been collected. The investigations were undertaken along routes (distance from 2 to 25 km) and permanent plots in ecotopes which are important for rare and relict species of flora. Overall, 360 leaves deposited in the herbarium were studied, with 216 geobotanic descriptions being mapped across 70 routes.

The research also includes analysis of the lists of rare and protected species of Kazakhstan plants (373 species) (Institute of Zoology and Scientific Society "Tethys" 1999), with the aim of defining biotopical preferences of the species in some families. A floristic diagram method, based on studies by Gnatyuk and Kryshen (2005), has been used to depict the relationships between different plant families. Statistical methods have been used to estimate the biodiversity of different biotopes. Alpha- and beta-diversity indices have been calculated using the indices of Whittaker and Shannon and assessed using cluster analysis (Dikareva and Leonova 2014).

## Results and discussion

Figure 5 shows the relative contributions of different plant families to the 175 rare and relict plant species observed. *Compositae* (17%), *Poaceae* (10%) and *Ranunculaceae* (10%) predominate. These families are followed by *Ammaryllidaceae*, *Liliaceae*, *Crassulaceae* and *Boraginaceae* (7% each). This correlation is mostly similar to the overall family correlation with all flora in a steppe area.

The highest indices of alpha- and beta-diversity were located on stream banks, valleys of temporary streams, lake banks, floating bogs in the limnetic zones of lakes, sphagnum bogs, raised bogs and swamp-subor forests, crevices of stone chunks, vegetation at the basis of rocky mountain ridges, pine forests on the flanks and shelves of high mountains with an understory of moss or moss and grass and sticky alder forests.

We divided the studied ecotopes into ten groups according to their importance for rare and relict species and identified groups of specific and unique ecotopes.

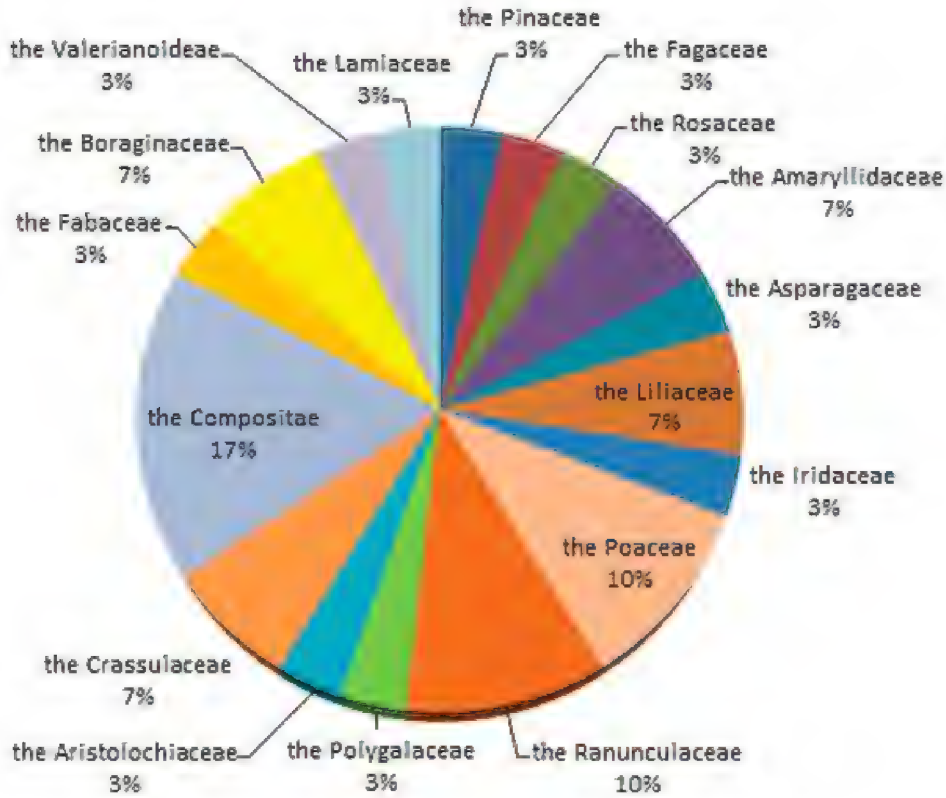


**Figure 5.** Floristic content of rare species in the Republic of Kazakhstan.

**Group 1. Stream banks and shady canyons. Most important**

This ecotype is the most important one for the conservation of rare and relict species. Species of the families Rosaceae (*Padus avium*, *Crataegus alpinum*, *Sorbus sibirica*, *Rubus idaeus*, *Filipendula ulmaria*), Grossulariaceae (*Ribes nigrum*, *Ribes hispidum*), Umbelliferae (*Heracleum sibiricum*, *Angelica sylvestris*, *Pleurospermum uralense*), Primulaceae (*Lysimachia vulgaris*, *Naumburgia thyrsiflora*), Compositae (*Ligularia sibirica*, *Crepis sibirica*), Equisetaceae (*Equisetum sylvaticum*, *E. pratense*) and Ericaceae (*Pyrola rotundifolia*, *P. minor*) dominate. Slightly less widespread are the species of the families Adoxaceae (*Viburnum opulus*), Onocleaceae (*Matteucia struthiopteris*), Athyriaceae (*Athyrium filix-femina*), Dennstaedtiaceae (*Pteridium aquilinum*), Cyperaceae (*Scirpus sylvaticum*), Rubiaceae (*Galium boreale*), Geraniaceae (*Geranium sylvaticum*) and Salicaceae (*Salix caprea*). Orchidaceae (*Dactylorhiza maculata*) was rarely seen.

**Group 2. Important**

This group includes sphagnum bogs, raised bogs and swamp-subor forests. They are characterised by families with species that are specific to the bogs of the northern taiga, as follows: Salicaceae (*Salex Lapponum*), Ericaceae (*Oxycoccus palustris*), Droseraceae (*Drosera potundifolia*, *D. anglica*), Cyperaceae (*Rhyncospora alba*, *Eriophorum angustifolium*, *E. gracile*, *Carex vaginata*, *C. loliacea*, *C. buxbaumii*, *C. rostrata*, *C. magellanica*), Scrophulariaceae (*Pedicularis palustris*, *P. sceptrum-carolinum*), Orchidaceae (*Spiranthes sinensis*) and Menyanthaceae (*Menyanthes trifoliata*). Some families grew on mounds. The representatives of these families, which usually grow in coniferous taiga, are Caprifoliaceae (*Linnaea borealis*), Orchidaceae (*Goodyera repens*) and Ericaceae (*Vaccinium vitis-idaea*, *Pyrola rotundifolia*, *P. minor*).

**Group 3. Intermediate importance**

Moss-grown and moss-grass-grown pine forests on the shoulders and tails of mountains are less favourable compared with the sphagnum bogs. The plant species, characterising these pine forests, belong primarily to the families Caprifoliaceae (*Linnaea borealis*), Orchidaceae (*Goodyera repens*, *Neottianthe cucullata*), Ericaceae (*Moneses uniflora*, *Chimaphila umbellata*, *Orthilia secunda*, *Pyrola chlorantha*, *P. rotundifolia*, *P. minor*) and Cystopteridaceae (*Gymnocarpium dryopteris*, *G. robertianum*, *G. tenuipes*).

**Group 4. Less important**

This group includes boil places, lakeshores and crevices of granite chunks in equal proportion. The following rare Orchidaceae were located near springs, with constant running and humifying water: *Cypripedium calceolus*, *Cyprepedium macranthon*, *Dactylorhiza fuchsia* and *Dactylorhiza maculata*. *Corallorhiza trifida* grew in the moss cover along the banks of streams that flow from springs. The following *Pyrola* species were observed: *Pyrola rotundifolia* and *Pyrola minor*. In addition, the fern *Gymnocarpium dryopteris* was found.

**Group 5. Lacustrine ecotopes**

Ecotopes of many rare boreal relicts, such as *Lycopodium clavatum* and *Diphasiastrum complanatum*, are located along the edges of lakes. On the edge of lakes in the pine forest, there are many individuals of the fern *Pteridium aquilinum*. A rare species, *Dryopteris carthusiana,* also grew here. On the lakeshores of Svetloe and Zerkalnoe in the Karkaralinskie mountains, the species *Trientalis europaea*, which is exceptionally rare for Kazakhstan, has been preserved. It grows in groups in the pine-birch forest on peaty soils, on pap at the base of birch trunks. *Equisetum hyemale* forms the entire tangle at the margin of Lake Borovoe in the mouth of the Imanayskiy well spring. *Vaccinium vitis-idaea* is located mainly close to lakes.

**Group 6. Rocky ecotopes**

Rocky inselbergs at the edges and on the sides of mountains and mountain uplifts are home to *Rubus idaeus* and the ferns *Asplenium septentrionale*, *Polypodium vulgare*, *Woodsia ilvensis* and *Cystopteris fragilis* which grow in crevices filled with fine grained soils. *Pentaphylloides fruticosa* and *Chamerion angustifolium* grow on the rocky edge of the Sinyukha mountain (southern side) and *Saxifraga sibirica* grows in shady moist crevices on northern side.

**Group 7. Sticky alder forests**

Black alder communities (*Alnus glutinosa*) are found in stream valleys and often in deep shady canyons that shelter many rare boreal relicts. Growth of boreal species in alder stands prefer abundant running humifying water, a wealth of soil, well-developed leaf-litter and a shadowing leaf canopy. *Circaea alpina*, *Circaea lutetiana*, *Delphinium elatum*, *Athyrium filix-femina*, *Matteucia struthiopteris* and others are found in this habitat type.

**Group 8. Seasonal ecotopes**

Two of the least important ecotopes for relict species are valleys of temporary streams and niches at the bottom of rocky edges of mountains in equal proportion. From the mountainsides in some places, streams flow down that are fully flowing after rains but dry up during dry summer periods. The boreal flora of the temporary stream valleys is less prevalent, including only *Ribes nigrum*, *Salix caprea*, *Solidago virgaurea*, *Rubus saxatilis*, *Galium boreale* and some others.

**Group 9. Rocky shelters**

On the northern sides of higher mountains and on mountain uplifts at the bottom of steep-sided rocky edges, snow usually accumulates in the winter and usually does not melt until the beginning or middle of June. There are shady places that offer shelter from the wind amongst large rocky inselbergs formed by a heavy layer of fine-grained soil. In these places, moisture is abundant as a result of melting snow and rain flowing down from the rocky edges as well as from the occurrence of condensation in crevices. Such shady niches serve as ecotopes for several rare relict plants. For example, *Juniperus communis* in the form of bunches and small trees (up to 3m), grow in the niches at the bottom of Sinyukha mountain in the Karkaralinskie mountains; however, in more open spaces, it takes the form of an elvin wood. *Rubus idaeus*, *Ribes nigrum*, *Athyrium filix-femina* and *Dryopteris filix-mas* were also observed.

**Group 10. Lacustrine floating bogs**

The least favourable ecotope for the conservation of rare species are the floating bogs in limnetic zones. The floating bogs on the lakeshores serve as distinctive ecotopes for the fern *Thelypteris palustris* which forms sporadic tangles. *Equisetum palustre* and *Equisetum fluviatile* were also observed.

The common feature of all these ecotopes is the presence of multiple rare and relict species that contribute to the high biodiversity and unique nature of the region (Fig. 6). This biodiversity is favoured by natural protection against fires, presence of a moisture reserve during dry periods, provision of ongoing stagnant semi-flow and flowing humification due to spring-well outlets, subsoil water proximity and water vapour condensation contained in the air and due to the damping impact of lakes.

The re-studies of vegetation of the evaluated areas have shown a gradual increase in species numbers and diversity, suggesting a favourable effect in the protection regime introduced in the national park and the decrease in grazing pressure (Dikareva and Leonova 2014). When composing recommendations to establish new strictly protected areas within the Karkaraly National Park, we took into account how much the ecotope favoured the existing high diversity of rare, relict and protected species (Fig. 7).

Thus, the annual floristic monitoring and biogeographical assessments of the ecotope's coverage of rare plant species allowed the identification of priority areas for Strictly Protected Natural Areas. These areas are primarily the stream banks, especially in deep shady crevices, sphagnum bogs, raised bogs and swamp-subor forests, as well as moss-grown and moss-grass-grown pine forests on the shoulders and tails of high mountains. Thus, for Karkaraly National Park, zoning is recommended based on the ecotopes with

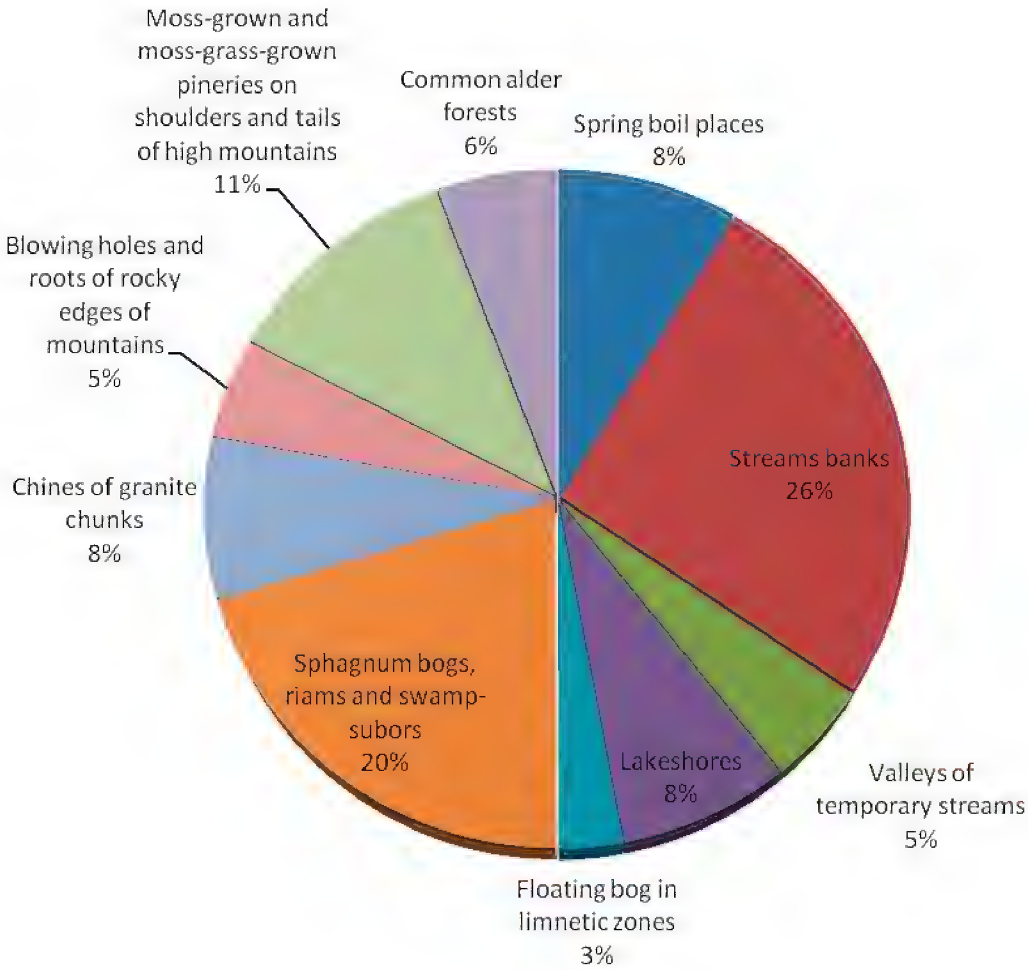


**Figure 6.** Percentage of rare species confined to a particular ecotope of the study area.

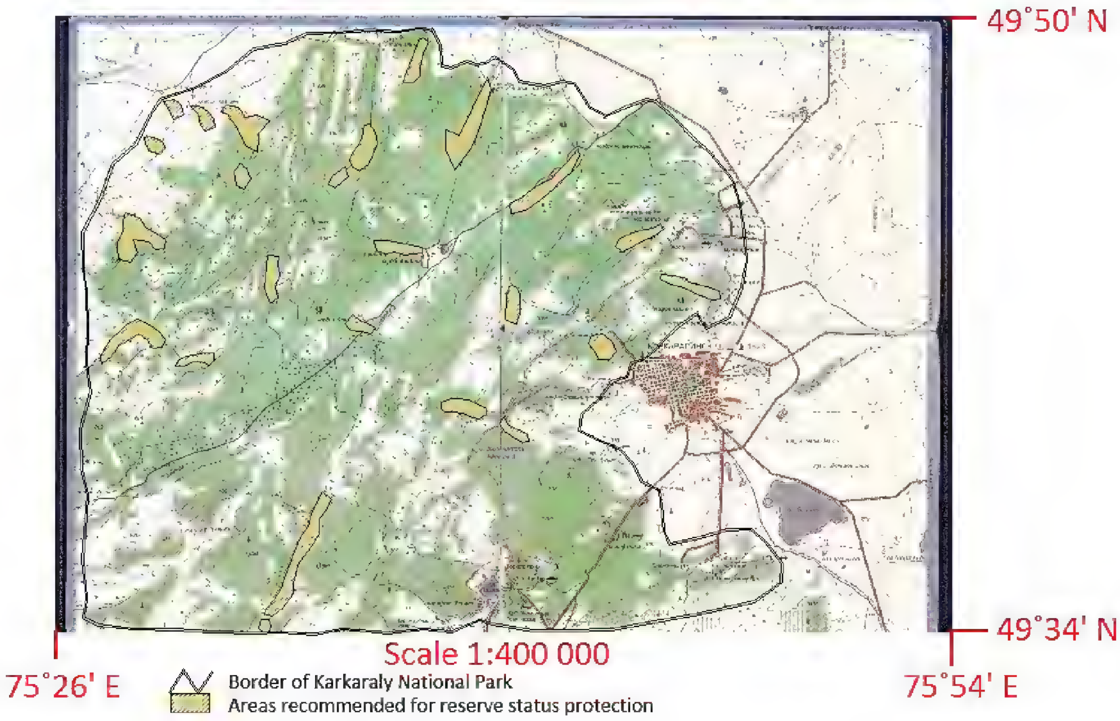


**Figure 7.** Existing protected territories and those that are recommended for protection in Karkaraly National Park.

the highest diversity of rare and relict plant species. In the shaded area on the map, protective measures, including prohibitions on visiting, should be imposed and regular monitoring should be undertaken. To improve the efficiency of the network of protected areas for the preservation of the unique plant biodiversity of the Karkaralinskie mountains, expansion of geobotanical research in this region must continue (Gerstner 2014).

## Case study 3: Kaliningrad region

The Kaliningrad region is unique in Russia; it is Russia's western enclave, both geopolitically and naturally. The region belongs to an inhabited urbanised territory that surpasses the Baltic States, Belarus and the North-West Federal region of Russia in population density, degree of urbanisation, intensity of agriculture and density of the traffic network. The high degree of agricultural development and deep transformation of natural complexes, wide development of hydro-engineering, transport and forest-based and agro-industrial systems greatly affect attempts to preserve landscapes and ecosystems in a near natural state to prevent the numbers and ranges of rare and endangered species of plants and animals from decreasing. Despite the existing network of special protected natural areas in the Kaliningrad region, the area's status and activities do not fully comply with modern conservational concepts and international obligations which Russia has regarding conservation of biological and landscape diversity. The traditional specificity of this area requires special measures for the conservation and recovery of the most important natural complexes that are of common European importance. This specificity also calls particular attention to compromises between conservational and economic interests. One approach may be the development of conservation strategies for rare species based on a detailed examination of the regional pattern of biodiversity.

### Natural Conditions

The Kaliningrad region is located on the western outskirt of the East European plain at the southeast coast of the Baltic Sea between 55°19'N and 54°19'N and 19°38'E and 22°52'E (Fig. 8). The region borders the Lithuanian republic to the north and east, Poland to the south and the Baltic Sea coastline to the west. The region's area, including waters, amounts to 15,100 km$^2$. The landscape is generally flat with predominantly vast low grounds in the central and northern parts (Pregolskaya, Polesskaya, Sheshupskaya, Nizhnenemanskaya) and in the uplands in the south (Varmiyskaya, Vishtynetskaya). These low grounds are characterised by a high diversity of origin and microrelief. Rare forms of relief are located in the territory's landscape, such as the deltaic plain of the Neman river, washed-over fens of the Curonian Lagoon coastline and sand spits (Curonian and Baltic) with wandering dunes which are unique to the Baltic region.

Based on natural and climatic conditions, the Kaliningrad region belongs to the south-taiga forest zone. The territory is characterised by abundant humifying, medium heat provision and a relatively steady temperature regime with a mild winter, cool summer and a long autumn period. The landscape of the Kaliningrad region has transitionary features between eastern and western Europe that are observed in the vegetation and soil layers of the territory. Zonal types of plants in the region's territory are represented by mixed broad-leafed fir forests (*Picea abies*, *Quercus robur*, *Carpinus betulus*, *Fagus sylvatica*) and nemoral forests with a grass layer that includes boreal floristic elements. Their differential characteristic is the high amount of broad-leafed


**Figure 8.** The region of study – Kaliningrad region.

species (up to 20%) and sticky alder (up to 15%), respectively. The region's territory is bordered with beech and fir forests. However, since the 17th century, the natural forest range has been cut down in the main part of the territory for grazing. Currently, the natural ecosystems of the Kaliningrad region are represented by forests, wetlands, meadows and dune complexes as well as the Baltic Sea water complexes. The biodiversity of the Kaliningrad region consists of 1,436 species of tall plants of which 26% are endangered and 338 terrestrial vertebrate species (mammals and birds), about half of which are rare and threatened (Dedkov and Grishanov 2010). Above the Kuronian Spit, about 20 million birds make their annual seasonal migration along the Belomor-Baltic route. The features of geographic location, historical development and natural conditions are the prerequisites and factors for high ecosystem diversity and biodiversity, the conservation of which is crucial for the whole European continent.

## Materials and methods

This study involved the authors' own field materials on rare and protected species of plants and animals gathered in 2000–2013 in the Kaliningrad region, the contemporary records of I. Kant Kaliningrad University and national and regional Red Book materials (Pavlov 2001, Dedkov and Grishanov 2010). All this data was compiled into a common database and then analysed and conceptualised using cartographic methods. The data included 83 species of high plants and 53 terrestrial vertebrate species (136 species in total), which have been under federal and regional protection for 80 years, including the time when the studied territory was a part of East Prussia.

The cartographic modelling of species was performed via grid mapping (a method of square grids). This method supported spatial statistical analysis of species distribution with a large amount of chronological data. This method was used for the first time in

Great Britain (Perring and Walters 1962) and then realised successfully in the course of a long-term project (1972–2010) on creating the Atlas "Flora of Europe" (Humpries et al. 1999, AFE (accessed: 14.12.2015). Flora mapping in these investigations is performed on a universal basis using a grid of squares on a geographical map of the same area, the borders of which include registering the species using a binary (presence or absence) approach. The opportunities for successful implementation of the square grid method for spatial analysis of the plants and individual groups of animals were shown by different authors (Bukhar and Koroleva 1994, Uotila 1999, Seregin 2012, Kalyakin et al. 2014).

Although European projects used a single-square (50×50 km) grid, no single grid was used for the territory of Russia. Thus, while performing regional investigations, researchers should create square grid systems of the actual region. For the Kaliningrad region, a subdominant double grid of squares (large and small) has been prepared using GIS-technologies (Sokolov 1999, Koroleva and Neronov 2007, Koroleva et al. 2008, Koroleva 2014). In the large-square grid, the grade frame is marked horizontally every 4' starting from 54°16' and vertically every 8' from 19°36'. Thus, the Kaliningrad region's territory was divided into 258 relative squares with an area of 63.75 $km^2$ each. All the squares had a number reflecting the horizontal structure of the grid and a letter identifying the squares by their vertical placement (for example, L14). For more precise localisation of the species location, each square is then divided into four sectors (each with an area of 15.94 $km^2$), marked by the letters a, b, c, d (Fig. 9). All the phases of mapping (create database, select series, draw maps) were undertaken using the programme MapInfo Professional, version 12.5.

The method of grid mapping was used for the Kaliningrad region, in addition to compiling traditional floristic and faunistic maps and this made it possible to perform a biogeographical assessment to detect the protected biota (flora and fauna), a benchmark assessment of historical floristic monitoring data and a current valuation of modern territorial conservation measures.

## Results and discussion

Separate distribution maps of protected plant and animal species, certain groups and families are the initial stages and transition elements of biodiversity mapping (Koroleva 2013). These maps reveal valuable information related to the protected species' territories, show the priorities in wildlife conservation and allow development of a strategy for conservation of rare species and their ecotopes in the region. "Hot spots" of biodiversity are identified by overlaying protected plant and animal species maps.

As can be seen from Figures 10 and 11, the priority biodiversity conservation areas in the Kaliningrad region include the Curonian and Baltic Spits, Sambiyskaya and Varmiyskaya Uplands, Sheshupskaya and Polesye Lowlands, Neman and Pregolya river deltas and the Curonian Lagoon coastline. The highest priorities amongst them are the Curonian Spit (over seven species in a square) and the Vishtynetskaya Upland (over six species), where the largest number of protected flora and fauna species are registered.

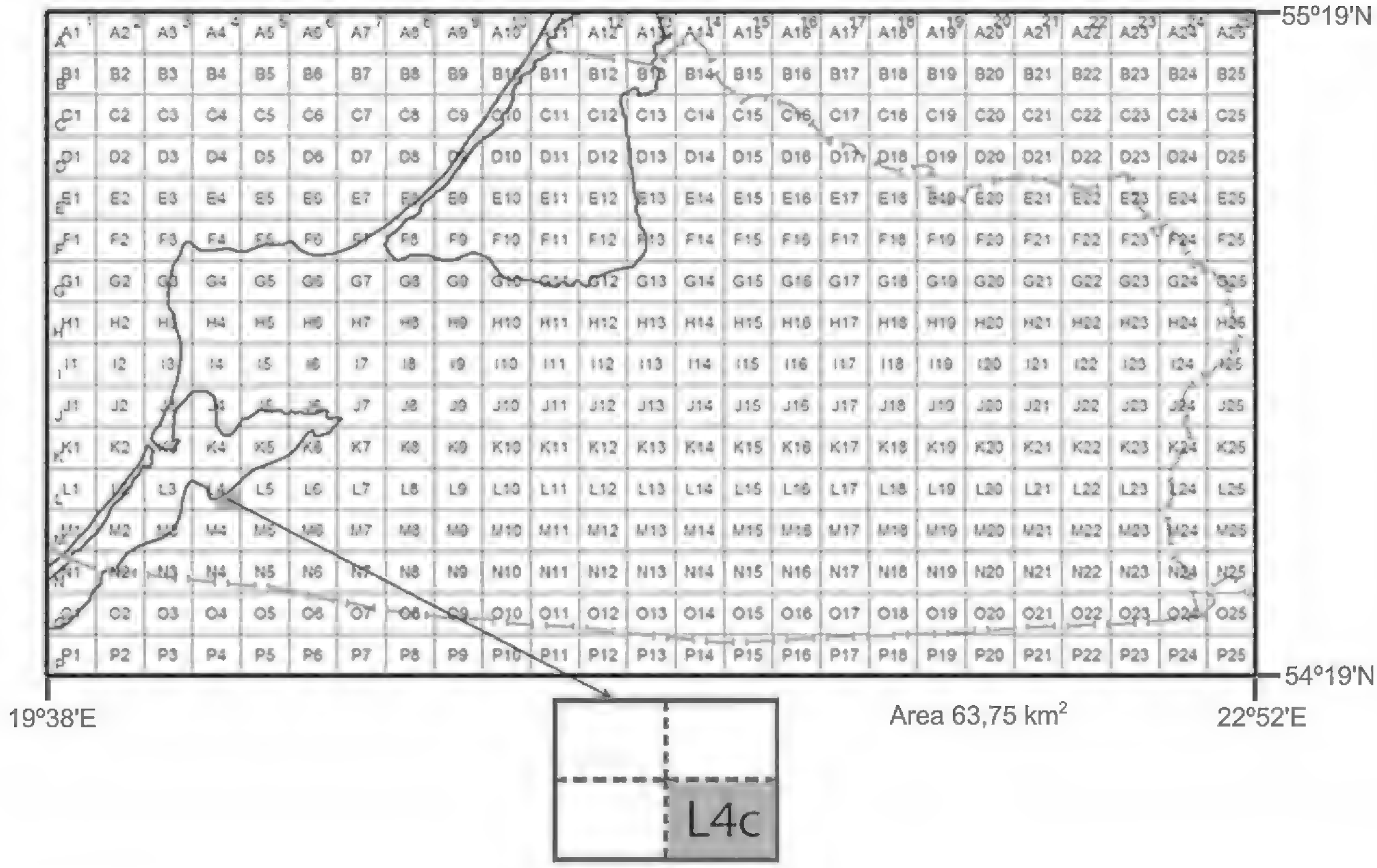


**Figure 9.** The square grid of the Kaliningrad region with an example of numeration of the "small square"

Dynamic trends in the distribution and/or disappearance of protected species using retrospective and modern mapping are shown in terms of the protected plants from the Red Book of the Russian Federation. The benchmark study of available archive materials from a historical perspective (until 1945) and with modern data allow the following conclusion to be drawn: The territories located east of Polesye and the south Gvardeyskiy districts showed fewer protected plant species in the last decade. The survey has also shown that, in the western and north-western regions, however, both the frequency of rare species and the amount of species in a single territory increased. This obviously testifies to the efficacy of protection measures in these regions. (Fig. 12).

Figure 12 shows the areas that require emergency protection measures due to the location of the species which are under international protection. These species are the orchid *Cypripedium calceolus* L. (lady's slipper), which is listed in the Red Book of IUCN and is found on the coast of Vistula Bay; *Epipogium aphyllum* Sw. (ghost orchid), which grows in the south Pravdinskiy district; and *Orchis morio* L. (green-winged orchis), which is known to grow in the Curonian Spit. Two further species are listed in the Convention on International Trade in Endangered Species of Wild Flora and Fauna. Four species are threatened with extinction in this area: *Botrychium simplex* E. Hitchc. (grape fern), which is observed on the coast of Vistula Bay, in the outskirts of Krasnoznamensk and Svetlogorsk and in the Curonian Spit; *Orchis mascula* L. (purple orchis), which grows in the Neman and Chernykhovskiy districts; *Gladiolus palustris* Gaudin (cornflag helobius), which is found only in the Pravdinskiy district; and *Taxus baccata* L. (common yew), which grows in the Krasnoznamenskiy district and in

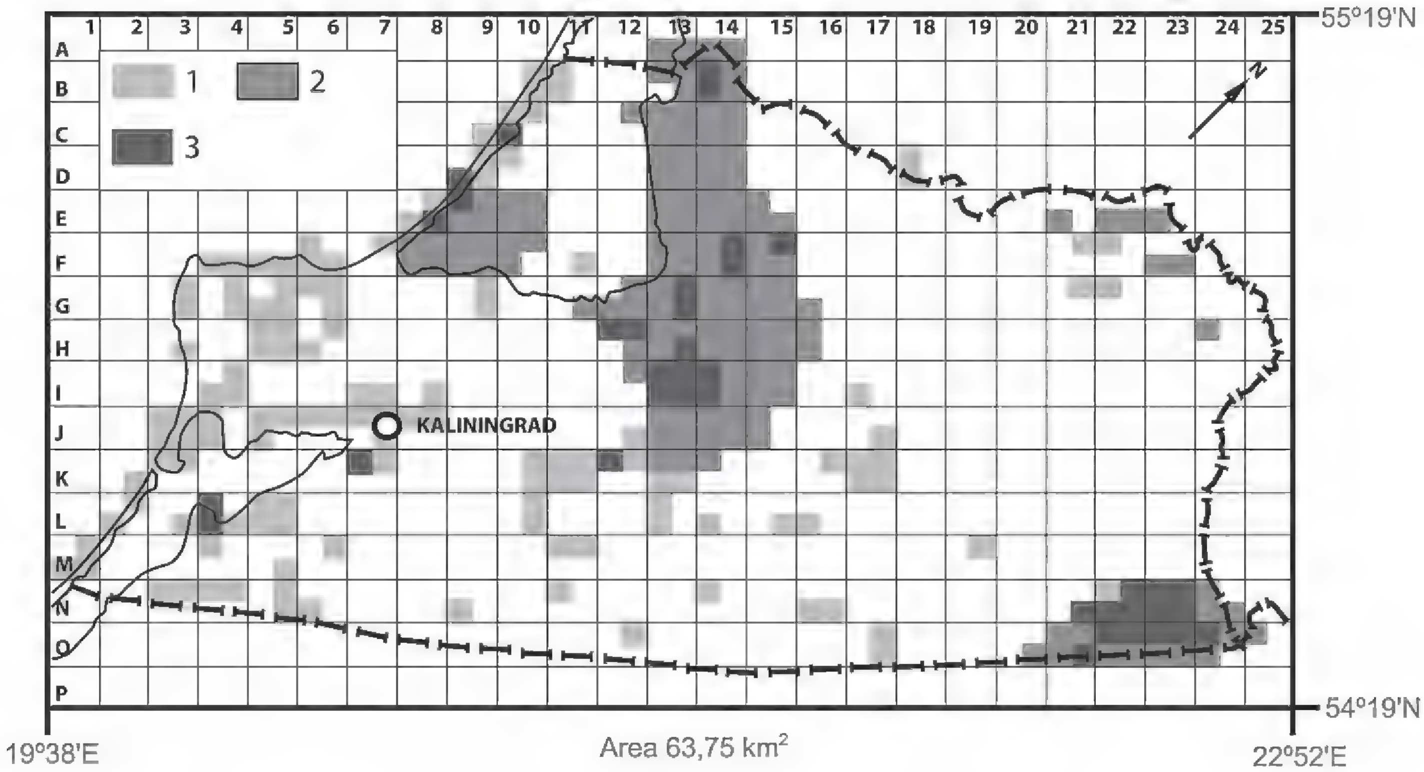


**Figure 10.** The protected plant and animal species spread in the territory of Kaliningrad region. **1** plants **2** animals **3** plants and animals

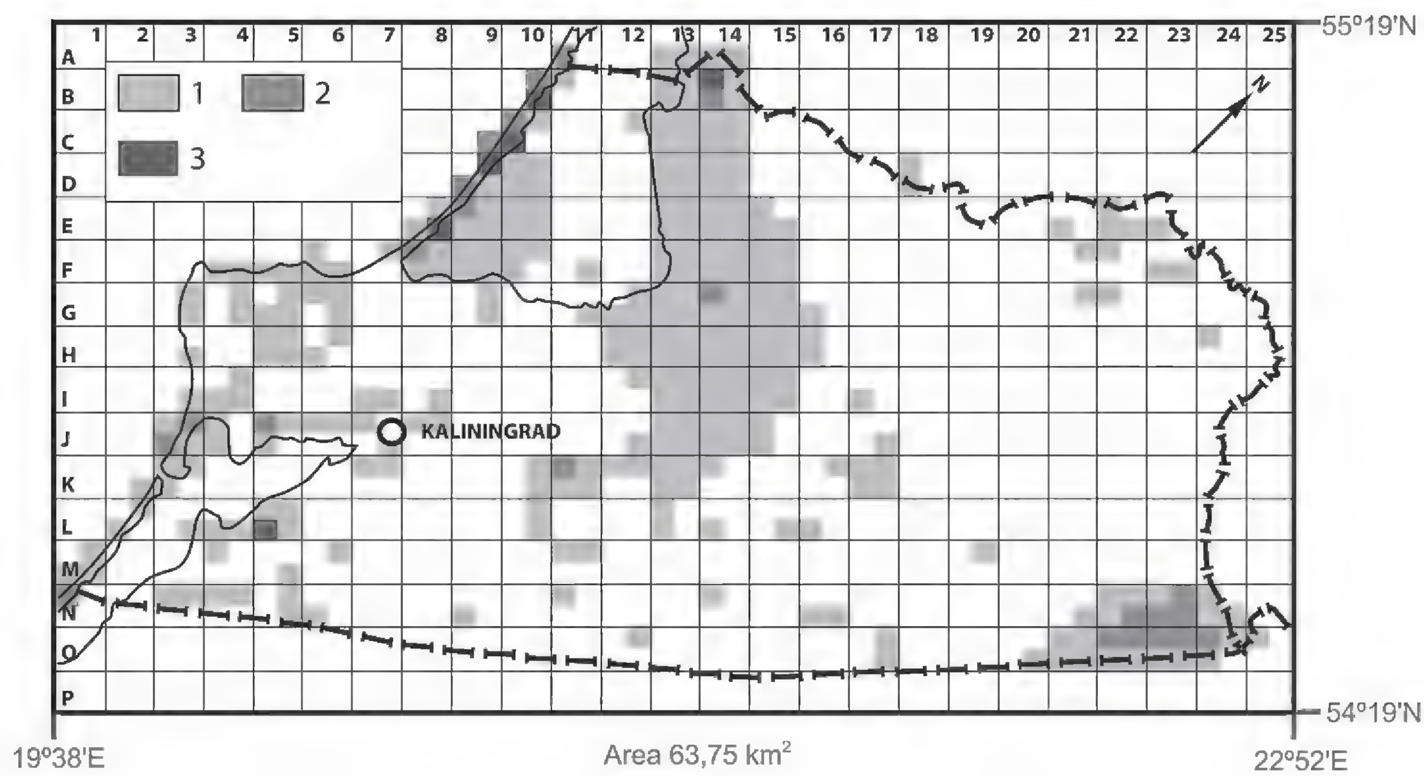


**Figure 11.** Species saturation (number of species in a square) of the protected plant and animal species in the territory of Kaliningrad region. **1** 1-3 species per square; **2** 4-6 species per square; **3** 7-9 species per square.

the outskirts of Kaliningrad. A large number of the protected species from the family *Orchidaceae* can be observed in the Kaliningrad region (Fig. 13).

Dimensional cartographical analysis of the protected biodiversity elements undertaken using GIS-technologies, databases and computer design reflects the historical and modern distribution of the protected flora and fauna species and shows how


**Figure 12.** The protected plant species distribution in the territory of Kaliningrad region in the middle of XX century (bottom figure) and early XXI century (top figure).

close they are to extinction in the range and region. This analysis also identifies the areas of high species richness. The key areas in the Kaliningrad region include the Curonian and Baltic Spits, the Sambiyskaya Upland and the coastline of the Sambiyskiy peninsula, Neman river delta, the Vishtynetskaya and Varmiyskaya Uplands, the Pregolskaya and Polessye Lowlands and Sheshupskaya Plain. Currently, less than 15% of the prioritised biodiversity conservation areas including the national park "Curonian Spit" (which is on the List of World Cultural and Natural Heritage UNESCO) are under territorial protection. For the rest, including the unique dune complexes, large forest ranges, watersides and upland moors, state protection measures do not apply. For valuable natural complexes, the Kaliningrad region has developed a range of conservation projects and offers, amongst which the most valuable align with the biogeographical assessment results. These projects and offers can be regarded as previously developed schemes in the specially protected areas (Tsybin 2004), providing different levels of protection at a world, Baltic, border and regional level. The scheme system of the specially protected areas has been created by taking into account the natural structure of the region, adjacent territories of neighbouring states and peculiarities of land use. The system includes all already existing specially protected areas while improving the conservation status of the most valuable ones in terms of landscape and biological diversity (i.e. the Vistula Spit, natural reserves "Gromovskiy" and "Dunnyi"). Additional specially protected areas, in which threatened species and unique ecosystems are located, are also included in the system. Realisation of this system will help to conserve natural complexes which have Baltic-wide importance and which represent an important natural element in the ecological network of Europe.

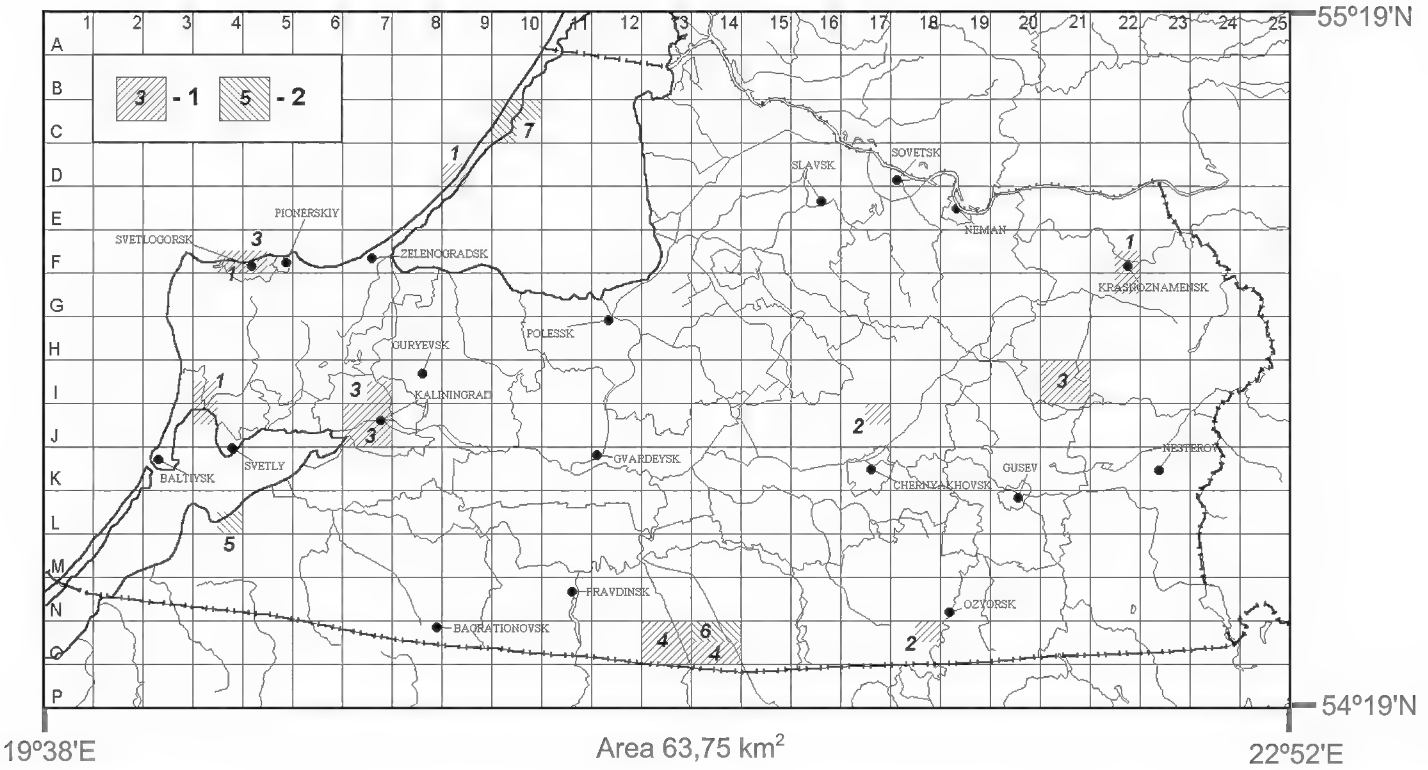


**Figure 13.** The plant species distribution for which there is a threat of extinction in the range. **A** species that are threatened with extinction in the range (under natural protection, category I) **B** species that are under international protection. The numbers designate the species: **1** *Botrychium simplex* E. Hitchc. **2** *Orchis mascula* L. **3** *Taxus baccata* L., **4** *Gladiolus palustris* Gaudin **5** *Cypripedium calceolus* L. (IUCN Red Book) **6** *Epipogium aphyllum* Sw. (Convention on International Trade in Endangered Species of Wild Fauna and Flora) **7** *Orchis morio* L. (Convention on International Trade in Endangered Species of Wild Fauna and Flora).

## Conclusions

Wildlife, biological and landscape diversity conservation is currently considered to be a leading direction of sustainable development. To realise this conservation, strategic documents (concepts) must be developed that define the formation of the regional (national) network of specially protected natural areas, which include, along with all typical, rare and unique landscapes, the ecosystems, separate communities and ecotopes of rare and endangered species from the Red Books.

Biogeographical approaches may serve as a basis for the development of concepts and implementation plans for regional biodiversity conservation. These approaches require researchers to undertake regular monitoring and quantitative accounting of biota, to analyse and assess the conservation value and biogeographical specificity of the territories, to define the priority and efficiency of the species and ecosystems conservation and to plan conservation undertakings.

The assessment of the number of *Anser erythropus* and *Haliaetus albicilla* and their breeding population size in the Subarctic under national and international protection shows the importance of the Putorana Plateau as a key region for reproduction of these species in the Asian part of Russia. This increases the plateau's conservation importance. Relict pine forest outliers in the steppe zone of Central Kazakhstan conserve many rare and endangered plants in favourable ecotopes. For these forests, we recommend a strict reserve status of conservation within the boundaries of Karkaraly

National Park. In highly urbanised regions (e.g. in the Kaliningrad region), where almost all the territories preserved in a natural state should be protected, an efficient and effective conservation principle should be realised. In accordance with that principle, the proposed conservation approach, differentiated by its level and priority, will help to conserve the most valuable natural complexes and objects that merit being included into a common European ecological network.

The three examples shown in this research belong to different geographical districts of the Palearctic region, with various degrees of exploration, anthropogenic transformation of the landscapes and development of protected natural area systems. The conducted research also differs by scale, object and method. However, they demonstrate new opportunities, generalisation, visualisation and cross-spectrum analysis of biologic and geographical information of conservation biogeography for practical conservation aims.

## Acknowledgements

The writing of this paper was supported by Russian Science Foundation project No. 14-50-00029.

## References

Pavlov DS (2001) The Red Book of the Russian Federation (Animals). AST, Astrel, Moscow, 845 pp.

Ackerly DD, Loarie SR, Cornwell WK, Weiss SB, Hamilton H, Branciforte R, Kraft NJB (2010) The geography of climate change: implications for conservation biogeography. Diversity and Distribution 16: 476–487. https://doi.org/10.1111/j.1472-4642.2010.00654.x

AFE (2003) Atlas florae Europaeae project. http://www.luomus.fi/en/atlas-florae-europaeae-afe-distribution-vascular-plants-europe [accessed: 14.12.2015]

Bukhar Ya, Koroleva EG (1994) Mapping for bioindication and nature conservation purposes. The Moscow University Herald. Series: Geography 6: 44–51.

Cadotte MW, Davies TJ (2010) Rarest of the rare: advances in combining evolutionary distinctiveness and scarcity to inform conservation at biogeographical scales. Diversity and Distribution 16: 376–385. https://doi.org/10.1111/j.1472-4642.2010.00650.x

Dedkov VP, Grishanov GV (2010) (Eds) The Red Book of the Kaliningrad Region. Immanuel Kant Russian State University, Kaliningrad, 333 pp.

Dementiev IA (1979) Iraq. Countries and Peoples. In: Proshin NI (Ed.) South-West Asia. Mysl', Moscow, 240–262.

Dikareva TV, Leonova NB (2014) Phytodiversity of the hills of Karkaraly National Park (Republic of Kazakhstan). Arid Ecosystems. Association of Scientific Editions of KMK, Moscow, 20, 4(61): 105–114.

Dorogov VF (1988) Birds of prey. The Fauna of Putorana Plateau, its rational use and protection, Proceedings of the Scientific-Research Institute of Agriculture of the Far North. V. Lenin All-Union Academy of Agricultural Sciences, Siberian Branch, Novosibirsk, 72–88.

Drechsler M (2005) Probabilistic approaches to scheduling reserve selection. Biological Conservation 122: 253–262. https://doi.org/10.1016/j.biocon.2004.07.015

Drechsler M, Lourival R, Possingham HP (2009) Conservation planning for successional landscapes. Ecological Modeling 220: 438–450. https://doi.org/10.1016/j.ecolmodel.2008.11.013

Ferrier S, Drielsma M (2010) Synthesis of pattern and process in biodiversity conservation assessment: a flexible whole-landscape modeling framework. Diversity and Distribution 16: 386–402. https://doi.org/10.1111/j.1472-4642.2010.00657.x

Franklin J (2010) Moving beyond static species distribution models in support of conservation biogeography. Diversity and Distribution 16: 321–330. https://doi.org/10.1111/j.1472-4642.2010.00641.x

Gallien L, Munkemuller T, Albert CH, Boulangeat I, Thuiller W (2010) Predicting potential distribution of invasive species: where to go from here? Diversity and Distribution 16: 331–342. https://doi.org/10.1111/j.1472-4642.2010.00652.x

Gerstner K, Dormann CF, Václavík T, Kreft H,Seppelt R (2014) Accounting for geographical variation in species–area relationships improves the prediction of plant species richness at the global scale. Journal of Biogeography 41: 261–273. https://doi.org/10.1111/jbi.12213

Gnatyuk EP, Kryshen AM (2005) Methods for Investigating Coenofloras (Example of Plant Communities in Harvested forest Areas in Karelia). Karelian Research Centre, Russian Academy of Science, Petrozavodsk, 68 pp.

Gordyagin AY (1897) About Kokshetau forests. Notes of the West Siberian Branch of the Russian Geographical Society 22: 1–18.

Gvozdetskiy NA, Mikhailov NI (1978) Physical Geography of the USSR – The Asian Part. Mysl', Moscow, 512 pp.

Hagemmeijer WJM, Blair MJ (1997) The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. T&A D Poyser, London, 903 pp.

Humphries C, Araújo M, Lampinen R, Lahti T, Uotila P (1999) Plant diversity in Europe: Atlas Florae Europeae and WORLDMAP. Proceedings of the VIII Meeting of the Committee for Mapping the Flora of Europe. Helsinki, Finland, 8–10 August 1997. Acta Botanica Fennica 162: 11–21.

Iknayan KJ, Tingley MW, Furnas BJ, Beissinger SR (2014) Detecting diversity: emerging methods to estimate species diversity. Trends in Ecology & Evolution 29(2): 97–106. https://doi.org/10.1016/j.tree.2013.10.012

Institute of Zoology and Scientific Society "Tethys" (1999) The Red Book of Kazakhstan. Bagheera Ltd., Astana, 550 pp. http://ozonit.ru/krasnaya_kniga/krasnaya_kniga_kazahstana.php

Walter KS, Gillett HJ (1988) IUCN Red List of Threatened Plants. International Union for Conservation of Nature and Natural Resources, Gland.

Kalyakin MV, Voltzit OV, Groot Koerkamp G (2014) The Atlas of the Birds of Moscow City. Fiton XXI, Moscow, 332 pp.

Karamysheva ZV, Rachkovskaya EI (1973) Botanical Geography of the Steppe Part of Central Kazakhstan. Nauka, Leningrad, 250 pp.

Kharitonov SP, Egorova NA, Korkina SA (2007) Birds and Mammals of the Agapa River Valley, Central Taimyr. Ecosystem Biodiversity of Putorana Plateau and the Adjacent Territories. Collection of scientific papers. Russian Agricultural Academy, Moscow, 91–113.

Koroleva E (2013) Biogeographical approaches for monitoring and biodiversity conservation: case study from Kaliningrad (Königsberg) region. Proc. of the XX Int. Conference on Environmental Indicators, 16–19 Sept. 2013, Trier, Germany, 10–12.

Koroleva EG (2014) Monitoring and mapping of biodiversity with the use of GIS technologies. Geoecology, geology and geography. Collective monograph XXIII. Publishing House of Herzen State Pedagogical University of Russia, St. Petersburg. 70–74.

Koroleva EG, Neronov VV (2007) Mapping and evaluation of the protected plants of the Kaliningrad region. The Moscow University Herald, Series 5. Geography 2: 60–67.

Koroleva EG, Neronov VV, Rumyantsev VV (2008) Principles and Methods of Creation of the Atlas of Protected Plant and Animal Species of the Kaliningrad Region. Biogeography in the Moscow University. GEOS, Moscow, 134–150.

Kozhechkin VV, Polushkin DM (1983) The number of white-tailed eagle in the valley of Vivi. Proceedings of the First Meeting on the Ecology and Protection of Predatory Birds. Nauka, Moscow, 122–123.

Kraft NBJ, Baldwin BG, Ackerley DD (2010) Range size, taxon age and hotspots of neoendemism in the California flora. Diversity and Distribution 16: 403–413. https://doi.org/10.1111/j.1472-4642.2010.00640.x

Krasheninnikov IM (1939) The main ways of vegetation of the Southern Ural in relation to paleogeography of the northern Eurasia during the Pleistocene and Holocene. Soviet Botany 6–7: 67–99.

Kuznetsov EA, Anzigitova NV, Anzigitov DV (2007) Notes on the bird fauna of the Nizhnyaya (Lower) Tunguski (Evenkia). In: Romanov AA (Ed.) Ecosystem Biodiversity of Putorana Plateau and Adjacent Territories. Collection of scientific papers. Russian Agricultural Academy, Moscow, 154–174.

Leung B, Cacho O, Spring D (2010) Searching for non-indigenous species: rapidly delimiting the invasion boundary. Diversity and Distribution 16: 451–460. https://doi.org/10.1111/j.1472-4642.2010.00653.x

Morozov VV, Syroechkovskiy Jr EE (2002) Lesser white-fronted goose on the verge of the millennium. Casarka 8: 233–276.

Nikolaev VA (1999) Landscapes of the Asian Steppes. Publishing House of the Moscow University, Moscow, 288 pp.

Norin BN (1986) General characteristics of vegetation. In: Norin BN, Belorusova (Eds) Mountain phytocenological Subarctic systems. Nauka, Leningrad, 164–168.

Ogureeva GN (2012) Ecological and geographical approach to the study of diversity and organization of terrestrial ecosystems. Questions of Geography Problem of Geography/Russian Geographical Society Moscow Center/Moscow, 1946–2012. Vol. 134: Actual Geography, Kodeks Publishing House, Moscow, 134, Current Biogeography, 58–80.

Perring FH, Walters SM (1962) Atlas of the British Flora. The Nelson, London, 432 pp.

Pospelov IN (2007) The avifauna of the western part of Anabar Plateau. In: Romanov AA (Ed.) Ecosystem Biodiversity of Putorana Plateau and Adjacent Territories. Collection of scientific papers. Russian Agricultural Academy, Moscow, 114–153.

Proença V, Martin LJ, Pereira HM et al. (in press) Global biodiversity monitoring: From data sources to Essential Biodiversity Variables. Biological Conservation.

Proshin NI (1979) Syria. Countries and peoples. South-West Asia. Mysl', Moscow, 188–211.

Rogacheva EV (1988) The Birds of Central Siberia. Distribution, Abundance, Zoogeography, Moscow, Nauka, 309 pp.

Romanov AA (2009) Distribution and population dynamics of the Falconiformes of Putorana Plateau (Average Siberia). Zoological Journal of Altai (Barnaul) 4: 52–57.

Romanov AA, Golubev SV, Melikhova EV (2014) Regularities of Spatial Differentiation of Fauna and Bird Population on Putorana Plateau. Contemporary Problems of Ecology 7(6): 618–627. https://doi.org/10.1134/S1995425514060110

Romanov AA, Rupasov SV (2009) The white-tailed eagle (*Haliaeetus albicilla*) in the north of Central Siberia. Bulletin of Moscow Society of Naturalists, Department of biology (Moscow) 114(4): 44–49.

Romanov AA, Rupasov SV, Zhuravlev EA, Golubev SV (2007) The birds the river Kureyki basin. In: Romanov AA (Ed.) Ecosystem Biodiversity of Putorana Plateau and Adjacent Territories. Collection of scientific papers. Russian Agricultural Academy, Moscow, 7–70.

Scoble J, Lowe AJ (2010) A case for incorporating phylogeography and landscape genetics into species distribution modeling approaches to improve climate adaptation and conservation in planning. Diversity and Distribution 16: 343–353. https://doi.org/10.1111/j.1472-4642.2010.00658.x

Seregin AP (2012) Flora of the Vladimir Region: Checklist and Atlas. Grif and K Publishing House, Tula, 620 pp.

Sokolov AA (2003) The method of square grids in the botanical studies of the Kaliningrad region. In: Dedkov VP (Ed.) Theoretical and Applied Aspects of Bioecology: Jubilee Collection of Scientific Works. Kaliningrad State University, Kaliningrad, 36–38.

Thomas CD (2010) Climate, climate change and range boundaries. Diversity and Distribution 16: 488–495. https://doi.org/10.1111/j.1472-4642.2010.00642.x

Thuiller W, Gallien L, Boulangeat L, Bello F, Munkemuller T, Roquet S, Lavergne S (2010) Resolving Darwin's naturalization conundrum: a quest for evidence. Diversity and Distribution 16: 461–475. https://doi.org/10.1111/j.1472-4642.2010.00645.x

Tishkov AA (2002) Nature Protection and Conservation. The Physical Geography of Northern Eurasia. Oxford regional environments. Oxford University Press, Oxford, 227–245.

Tsybin YuI (2004) (Ed.) The scheme of nature conservation of the Kaliningrad region. TENAX MEDIA, Kaliningrad, 136 pp.

Uotila P (1999) Chorological Problems in the European Flora. Proceedings of the VIII Meeting of the Committee for Mapping the Flora of Europe. Helsinki, Finland, 8–10 August 1997. Acta Botanica Fennica 162: 1-197.

Velasco D, García-Llorente M, Alonso B et al. (2015) Biodiversity conservation research challenges in the 21st century: A review of publishing trends in 2000 and 2011. Environmental Science & Policy 54: 90–96. https://doi.org/10.1016/j.envsci.2015.06.008

Volkov AE (1988) On the fauna and population of birds from the Kotuy River basin and the neighbourhood of Poselka Tura. In: Rogacheva EV (Ed.) Protection and rational use of fauna and ecosystems of the Yenisey North. IEMEZH, USSR, 97–112.

Zyryanov VA (1988) The avifauna of Lake Nerangda surroundings. The Fauna of Putorana Plateau, its rational use and protection, Proceedings of the Scientific-Research Institute of Agriculture of the Far North. V. Lenin All-Union Academy of Agricultural Sciences, Siberian Branch, Novosibirsk, 88–96.